The background of the slide is a composite image. In the upper left, there is a bright, glowing spiral galaxy. A diagonal streak of purple and white light, representing a cosmic ray shower, cuts across the center of the image. The lower half of the image shows a blue, textured surface, likely representing Earth's atmosphere or ocean. In the top right corner, there is a small inset image showing a network of lines, possibly representing the detector array of the Pierre Auger Observatory.

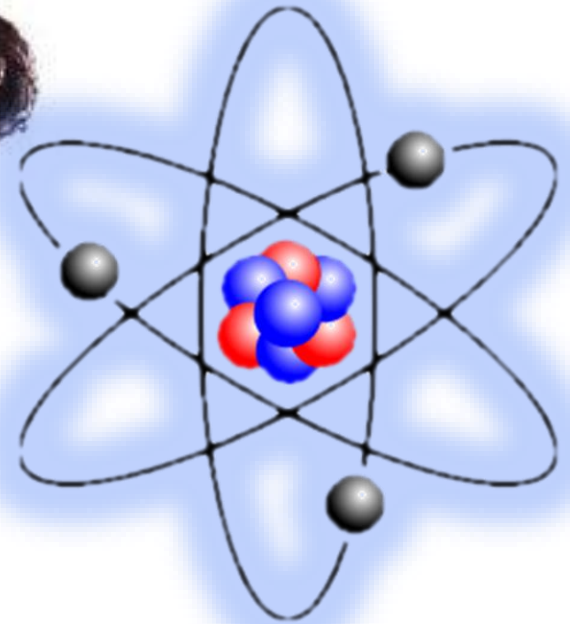
Pierre Auger Observatory
studying the universe's highest energy particles

The Highest Energy Cosmic Rays

***Mysterious Messengers
from a
Violent Universe***

Paul Mantsch
Scientist Emeritus - Fermilab

Humankind Ponders the universe



Pondering the Universe

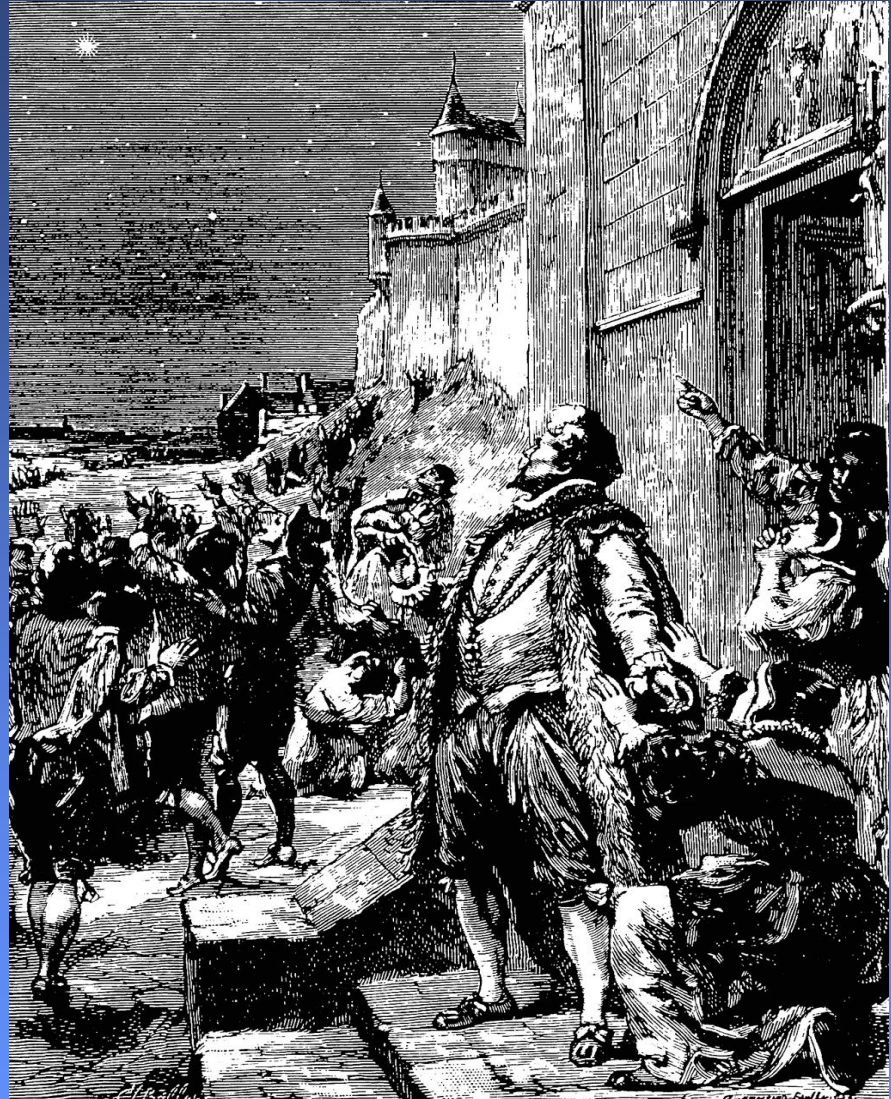
What is the universe made of?

What are we made of?

What is matter?

What is gravity?

How did the universe form
and evolve?

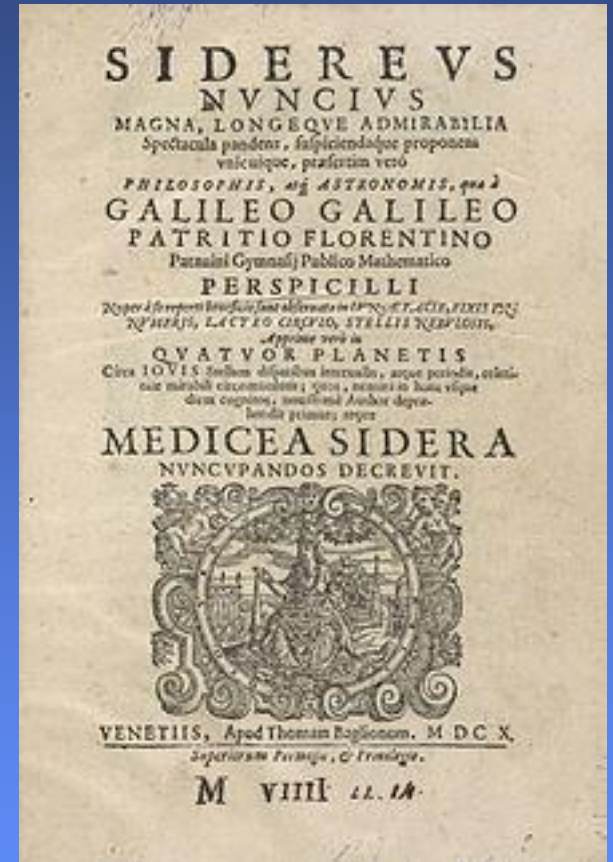


Tycho Brahe 1572

Searching for answers



Galileo Galilei



The Starry Messenger - 1610

Why should we care?

We are made of stuff of our universe

**Moreover - scientific knowledge of
natural world molds our lives.**

Besides we humans are just curious!

The power of science

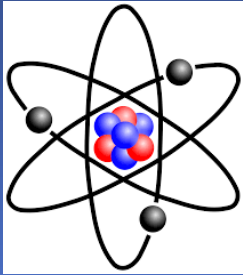


1. Observation
2. Theory
3. Test
4. new understanding
5. Back to 1

Scientist at work

At Fermilab we explore:

Depths of the atom



and the



Depths of the cosmos



Exploring the mysteries of the universe

These are exciting times!

Higgs Boson

(nature of mass)

Gravitational Waves

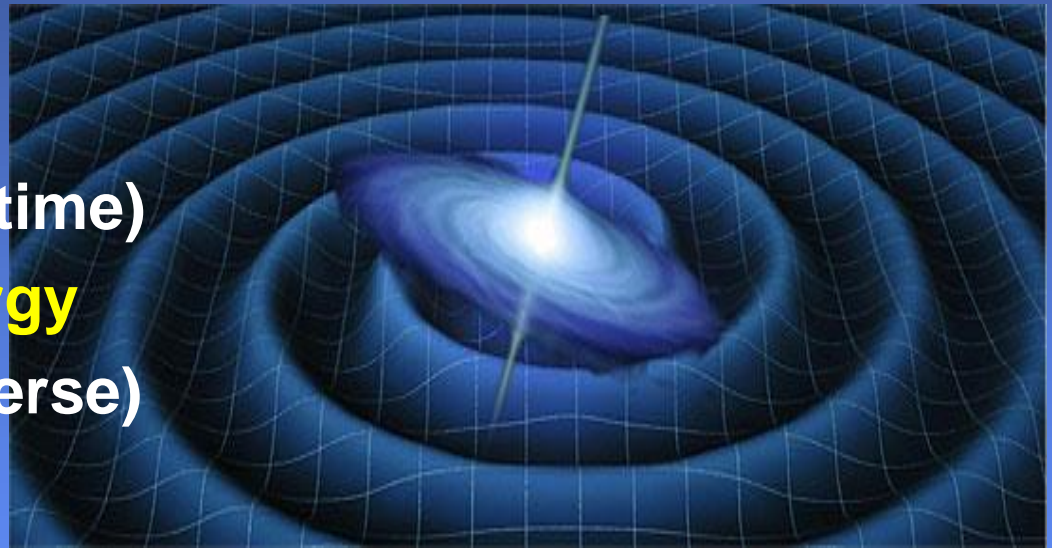
(ripples in spacetime)

Dark Matter / Dark Energy

(stuff of the universe)

Particles from space

(cosmic messengers)



Victor Hess discovered particles from space



Victor Hess flies over the Alps - 1912

Natural Radiation is all around us (rays and particles)

Electro-magnetic radiation

Infrared light

Visible light

Ultraviolet light

Gamma rays

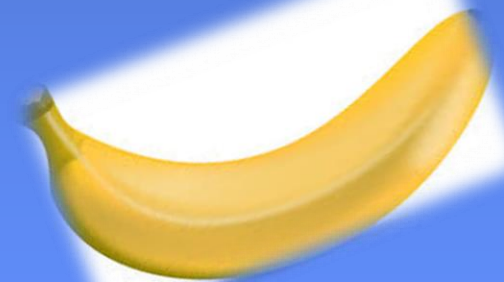
Natural radioactive decay (radium, radon, potassium etc.)

Beta particles (electrons)

Alpha particles

Neutrinos

Cosmic particles from space



The highest energy cosmic rays – mysterious messengers from the cosmos

***The most energetic particles observed
in nature!***

What are cosmic rays?

Where do they come from?

How do some get such enormous energy?

What do they tell us about violent cosmic processes?

What can they tell us about ourselves?

Observing cosmic rays

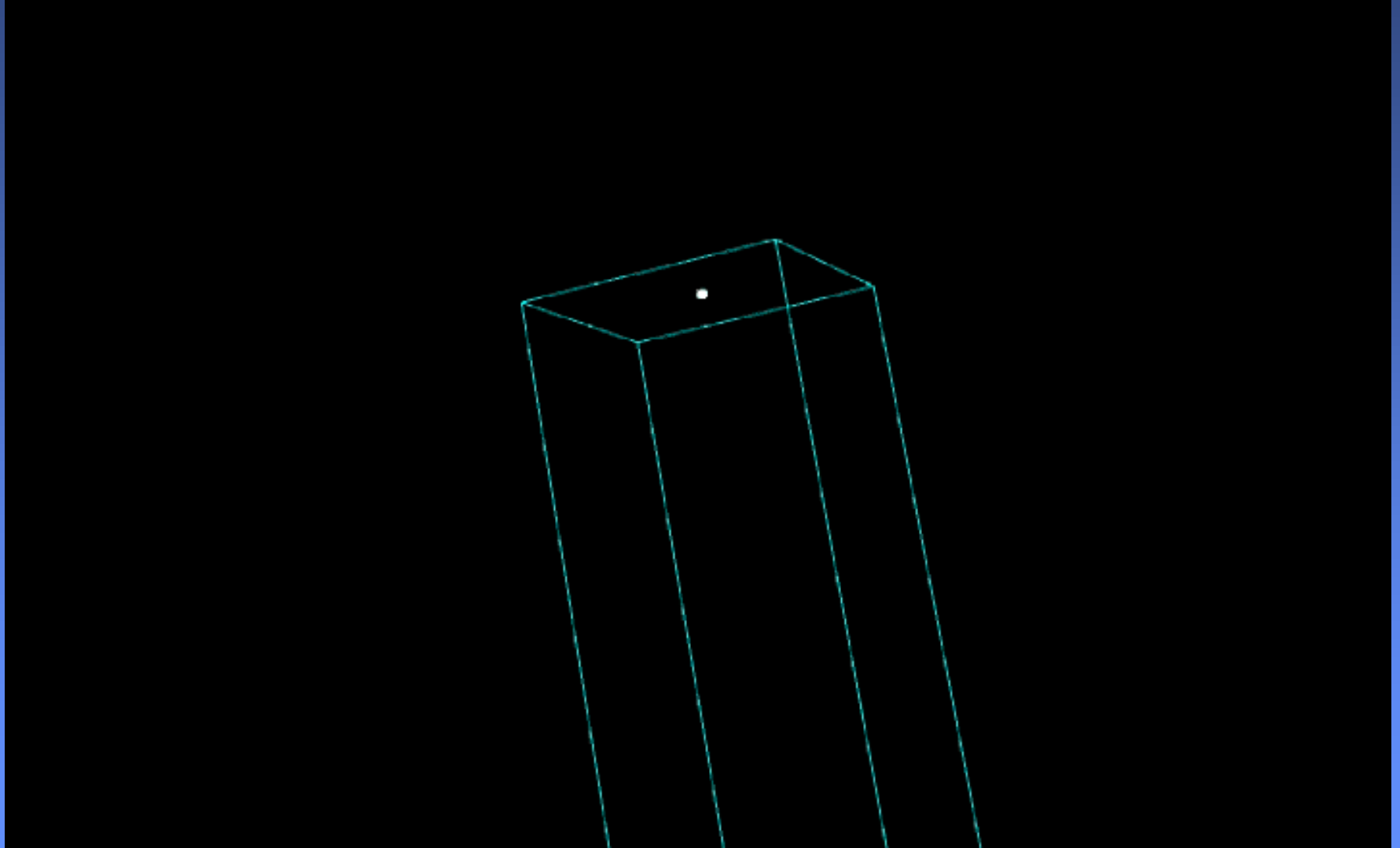
Air showers

- Cosmic Rays smash into molecules in the atmosphere making many new particles
- Millions of particles at the earth

The atmospheric protects us.



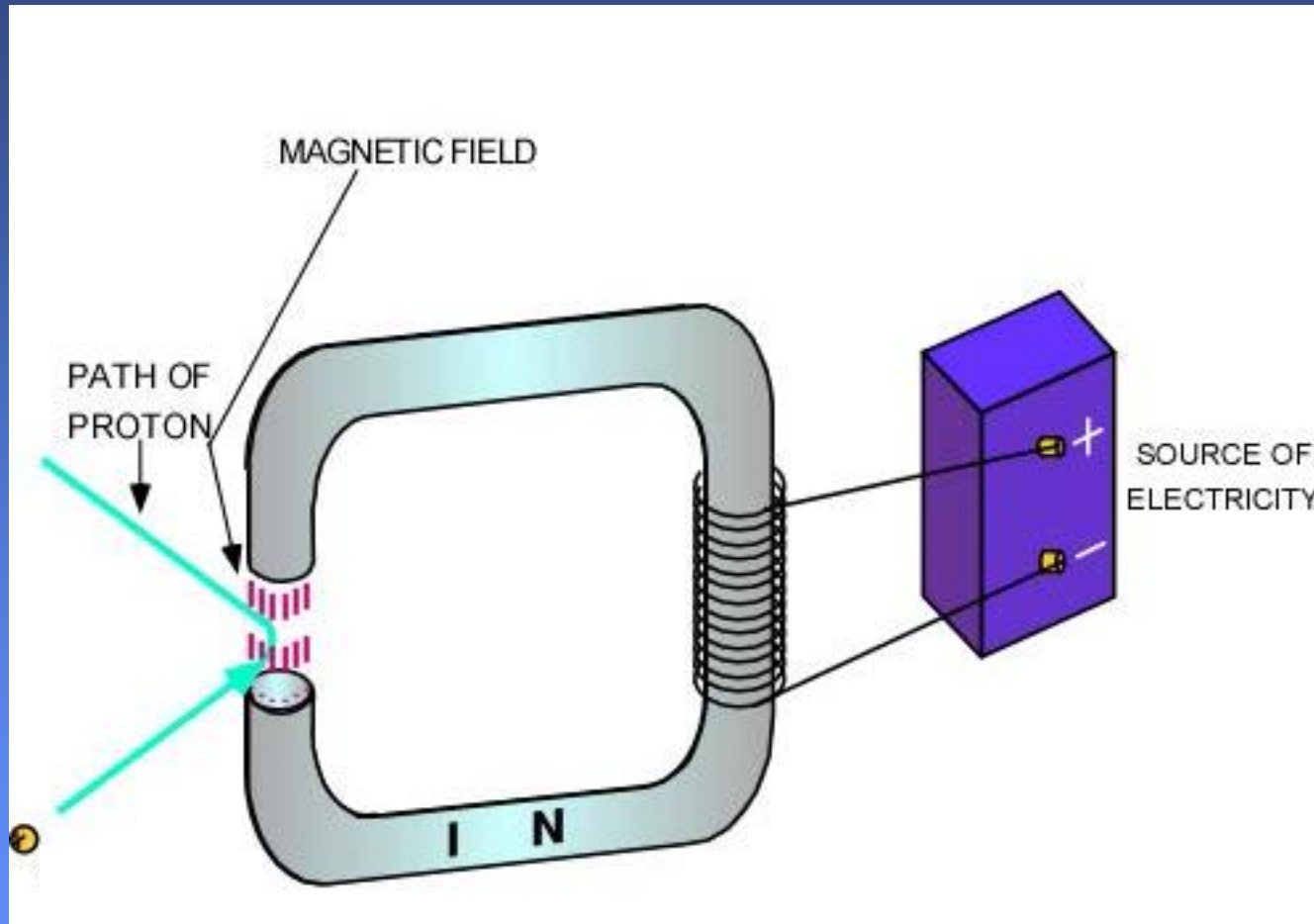
A simulated high energy cosmic ray shower



Cosmus: [Randy Landsberg](#), [Dinoj Surendran](#), and Mark SubbaRao (U of Chicago / Adler Planetarium)

What is a Particle Accelerator?

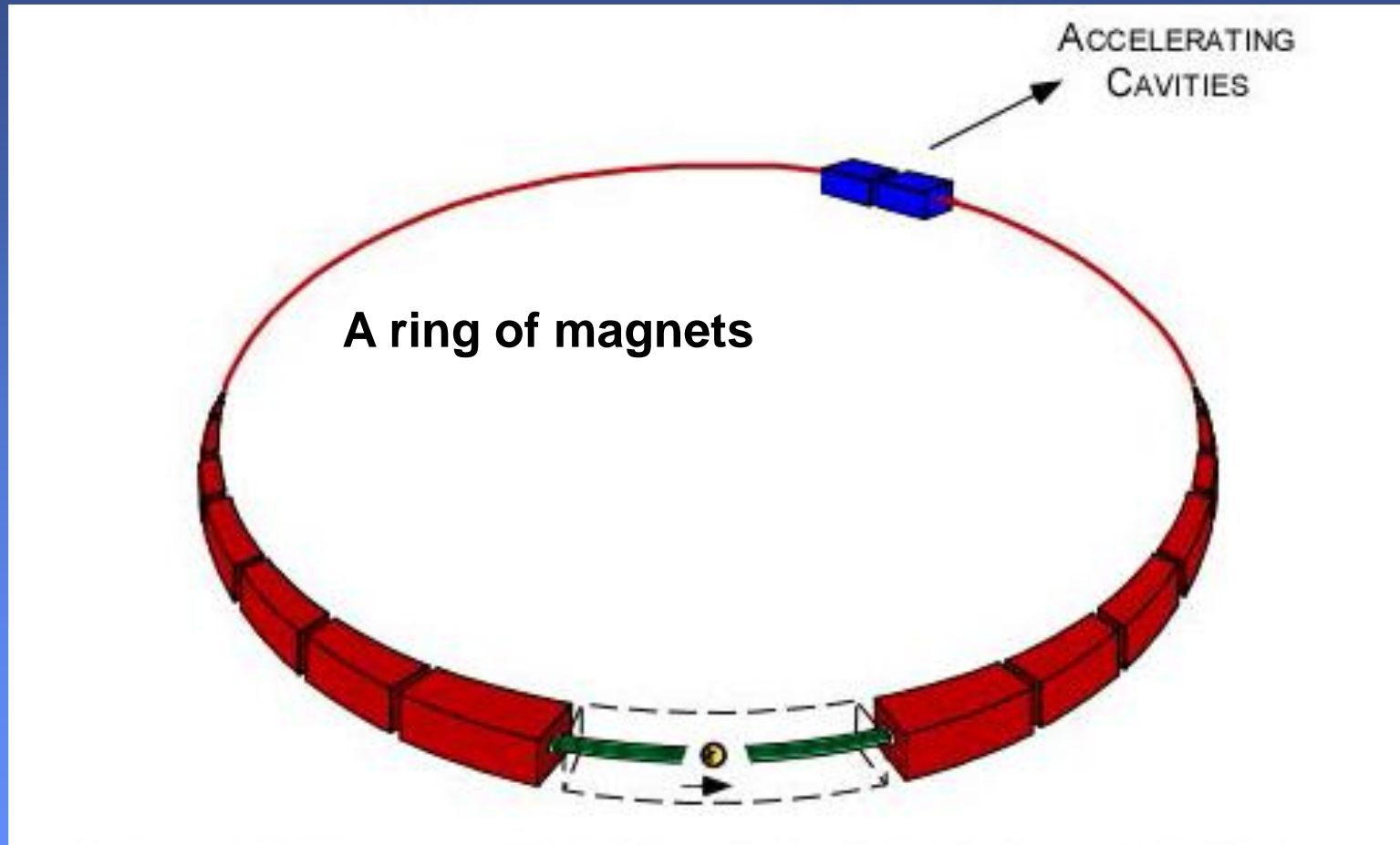
How they work



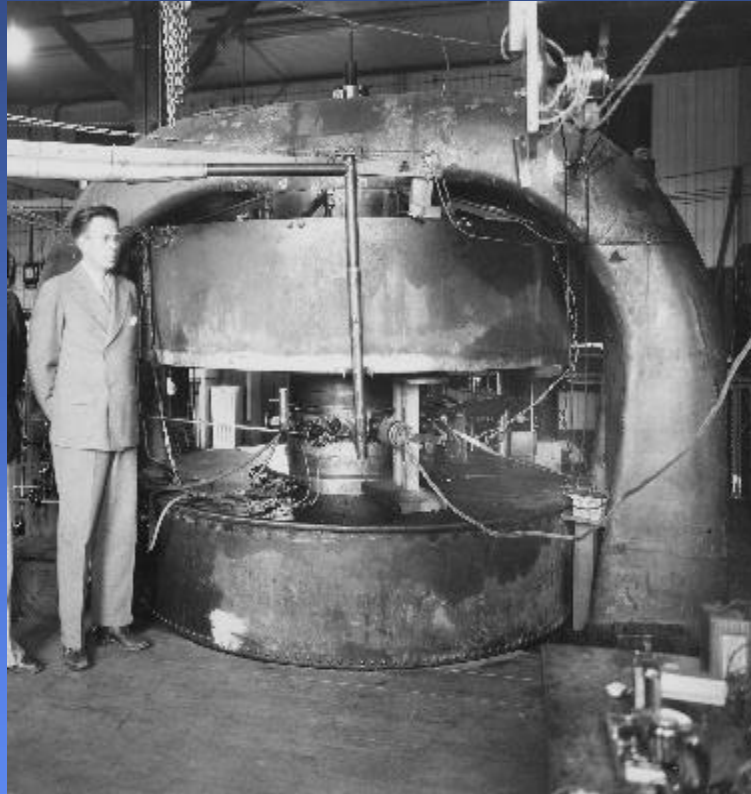
Moving charged particles are bent by
magnetic fields

Particle Accelerators

How they work



Particle accelerators



Ernest Lawrence's first
cyclotron - 1930's

**Just how energetic are these
particles from space?**

Modern particle accelerators



4 miles around

**Tevatron at Fermilab -
 10^{12}eV**



17 miles around

**LHC CERN Geneva—
 $7 \times 10^{12}\text{eV}$**

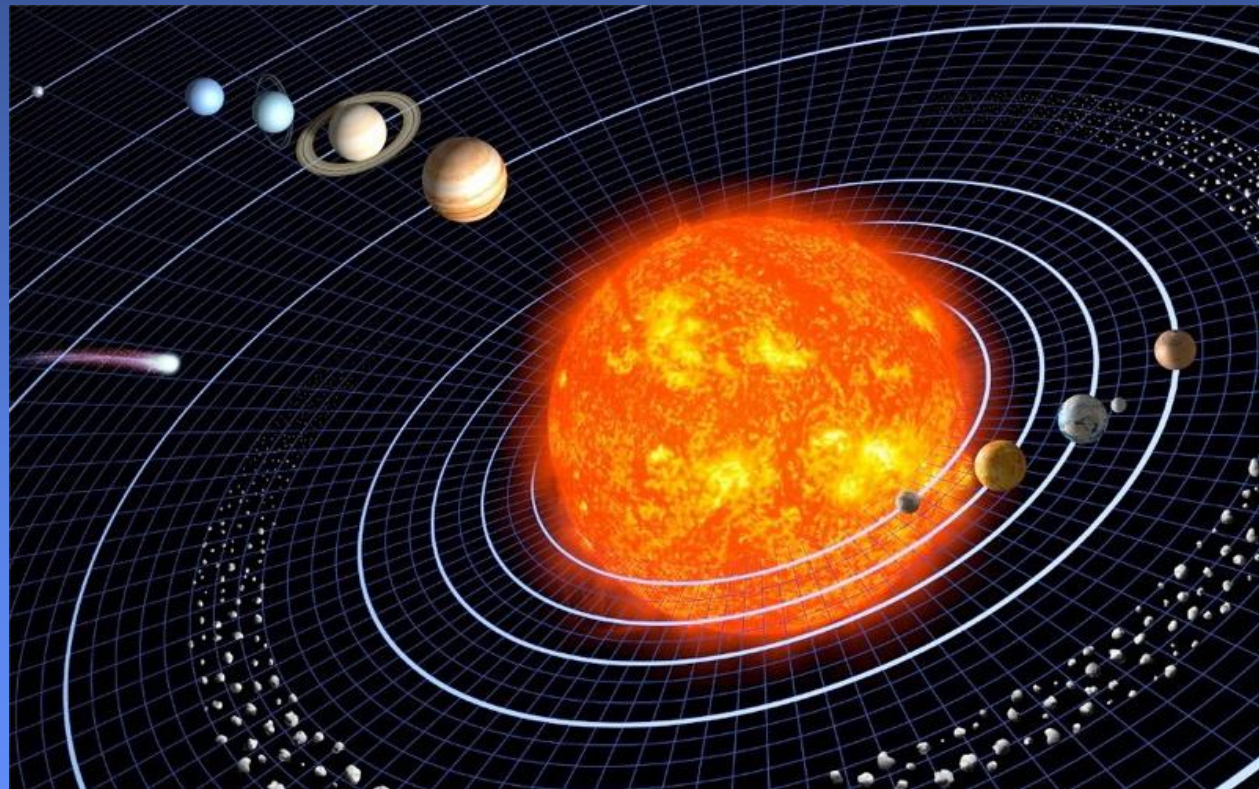
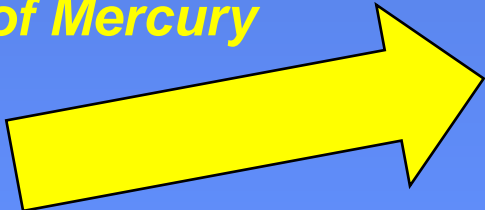
$(10^{12}\text{eV} = 1,000,000,000,000\text{ eV})$

Just how energetic are these particles from space?

The highest
energy cosmic
rays – 10^{20} eV

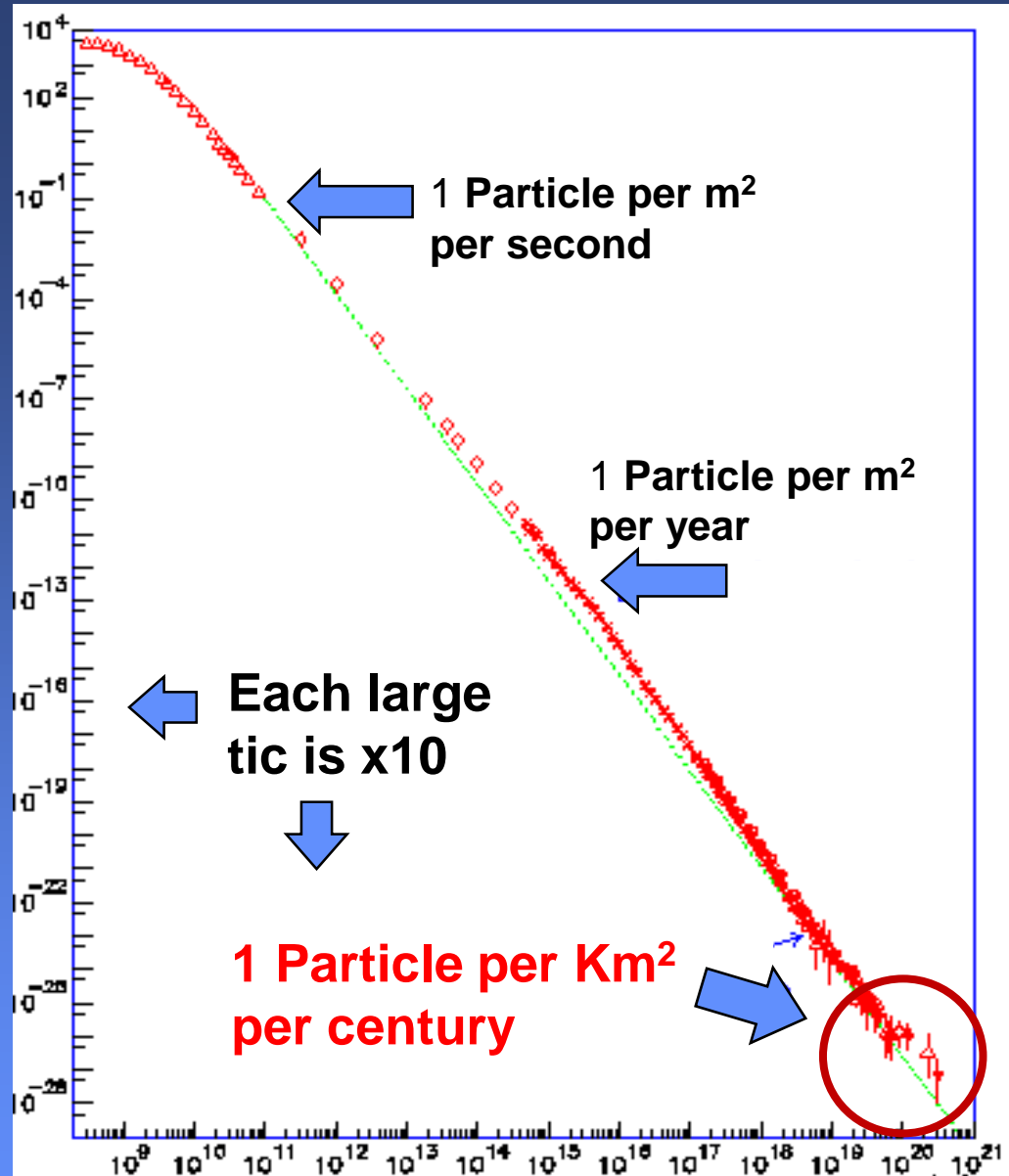
*(1,000,000 times
more energetic)*

*Present technology
would require an
accelerator the
diameter of the orbit
of Mercury*



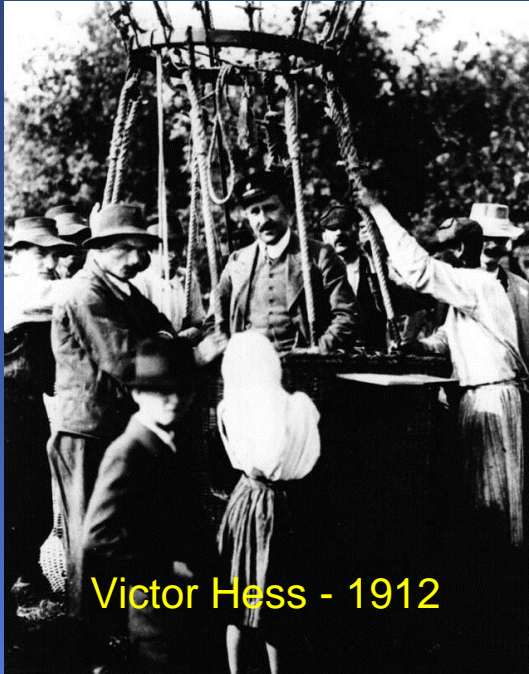
The cosmic rays from space- (the spectrum)

Flux ($\text{m}^2 \text{sr s eV}^{-1}$)



Energy (eV)

Adventures in Cosmic Ray Physics



Victor Hess - 1912



Pierre Auger and Paul Ehrenfest - 1939



Georgi Zatsepin - 1946

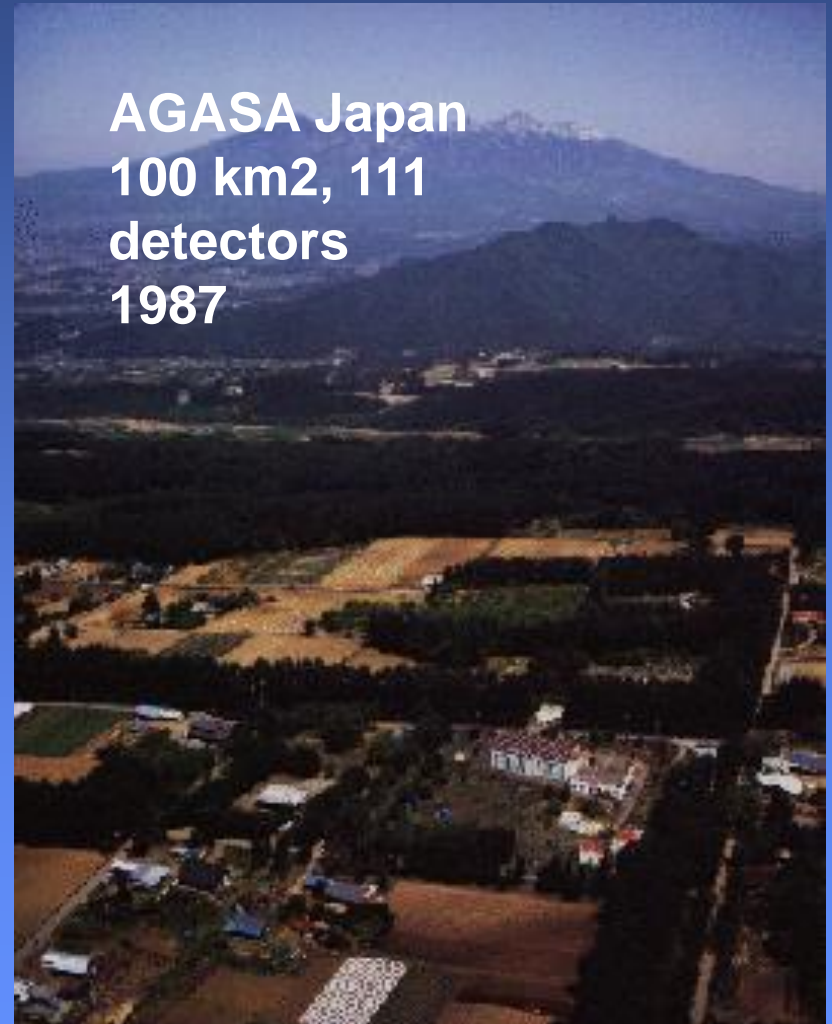


John Linsley -
1962

More, bigger cosmic ray detectors



High Resolution Fly's Eye
Utah
Telescopes
1981



AGASA Japan
100 km², 111
detectors
1987

Building the Pierre Auger Observatory



**Jim Cronin and Alan Watson –
*the concept - 1991***



**The Giant Array Workshop
*Fermilab - February to July, 1995***

The Auger Collaboration

90 Institutions, >450 Collaborators

			
Argentina	Australia	Bolivia	Brasil
			
Czech Republic	France	Germany	Italy
			
Mexico	Netherlands	Poland	Portugal
			
Slovenia	Spain	United Kingdom	USA
			
Vietnam			

Argentina

Australia

Bolivia*

Brazil

Czech Republic

France

Germany

Italy

Mexico

Netherlands

Poland

Portugal

Slovenia

Spain

United Kingdom

USA

Vietnam*

* associate



A Model for International Science

True International Partnership

No country, region or institution dominates



The Observatory Site

Mendoza
Province,
Argentina
(Near the city of
Malargüe)



Raising funds

Lafalla con el Premio Nobel Cronin, Menem y Decibe Todos ponen para el observatorio

LOS ANDES



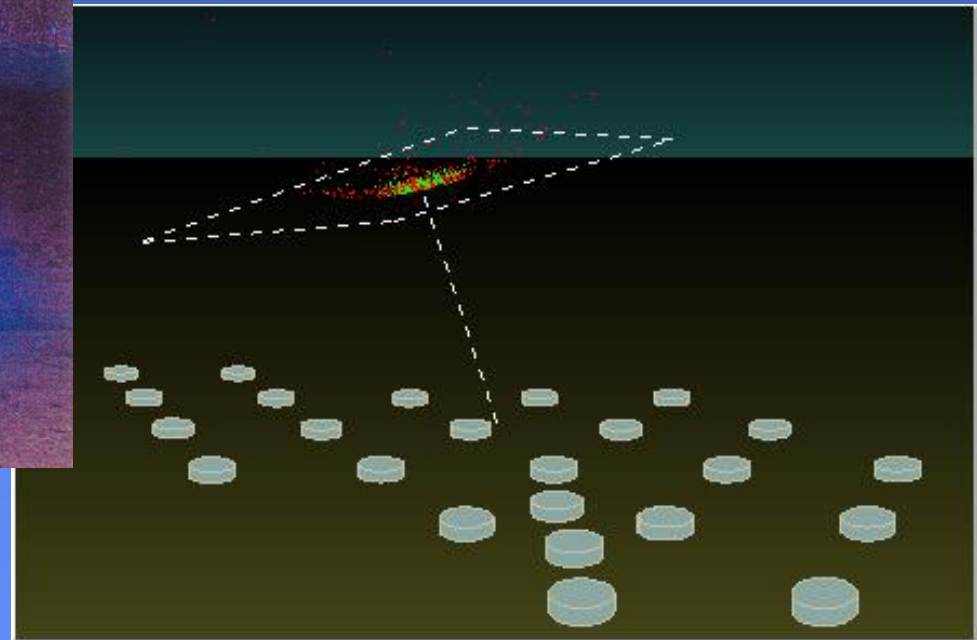
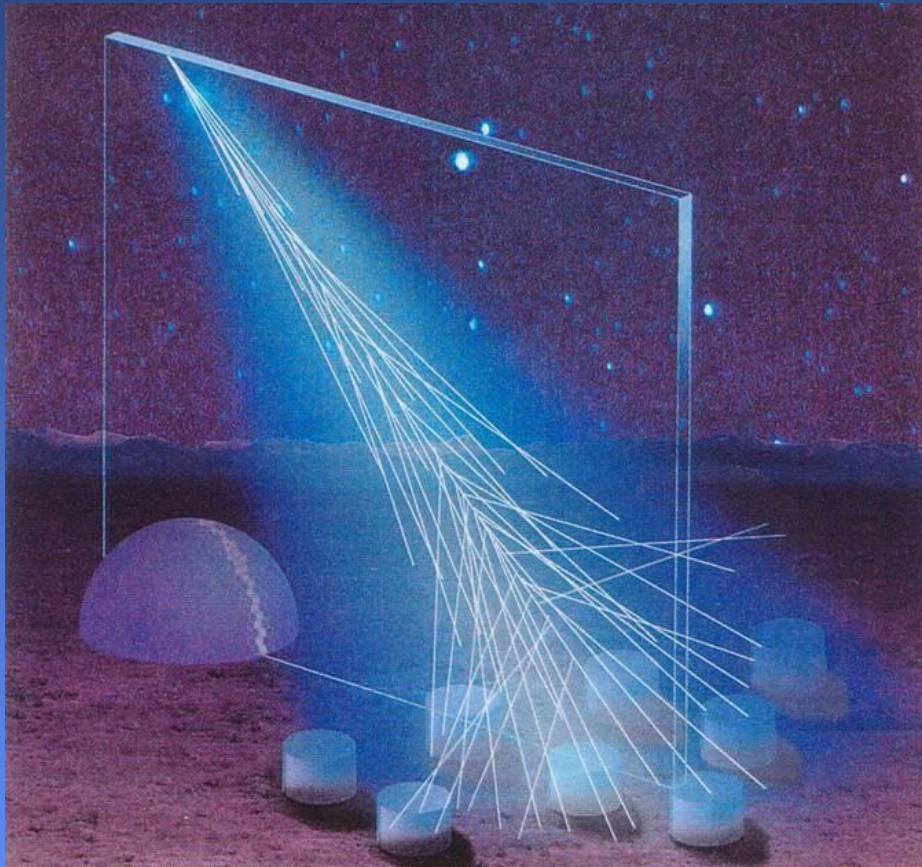
El gobierno nacional participará con diez millones de pesos del observatorio de rayos cósmicos que se instalará en Mendoza. La Provincia aportará otros cinco. Hay 19 países en el proyecto. (Información en página 2, 2a. sección)

Jim Cronin and Alan Watson
toured the world
promoting the
project

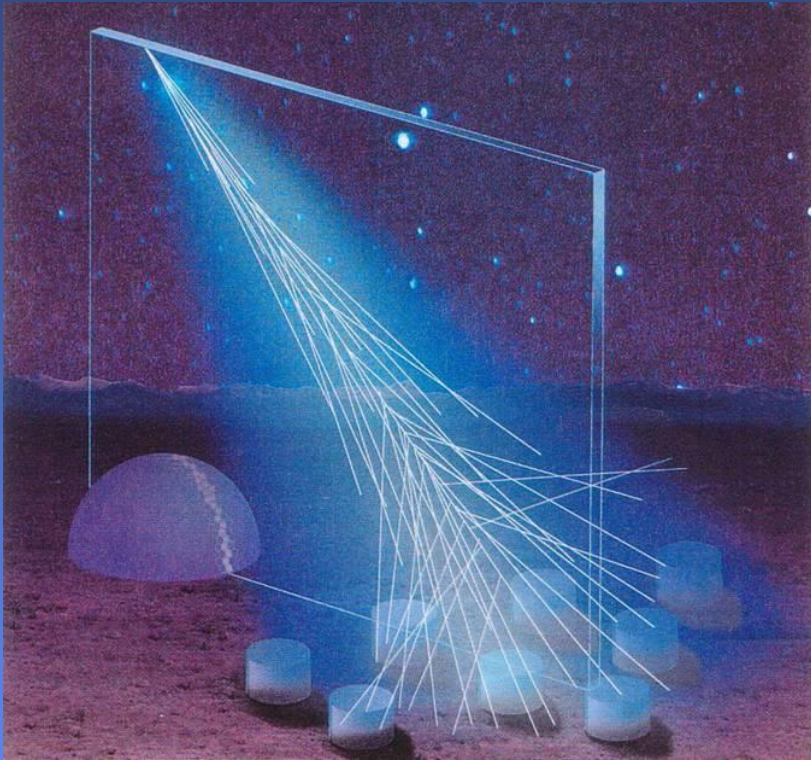
Los Andes
10 September 1998

The Design

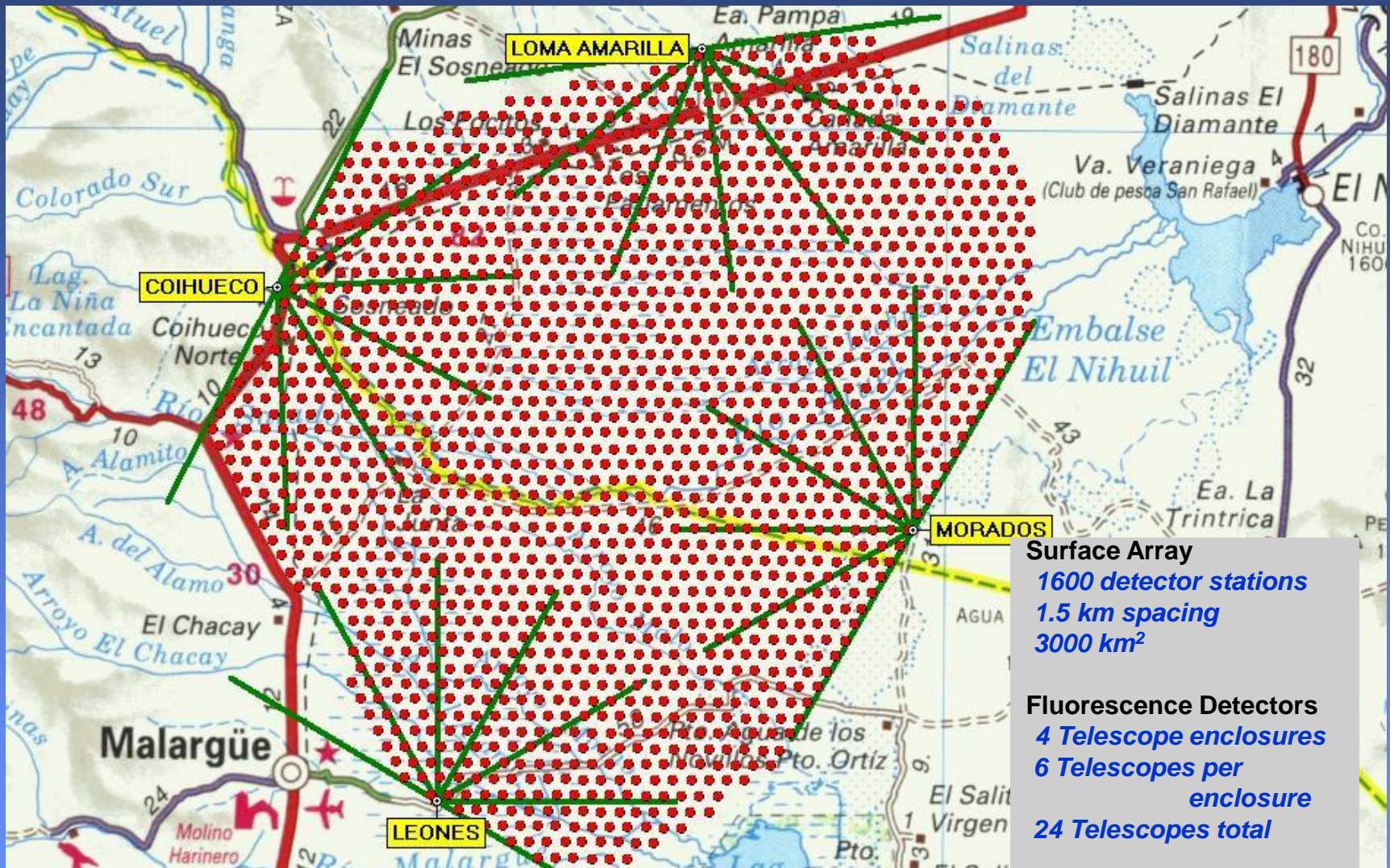
Surface detector array + Air fluorescence detectors



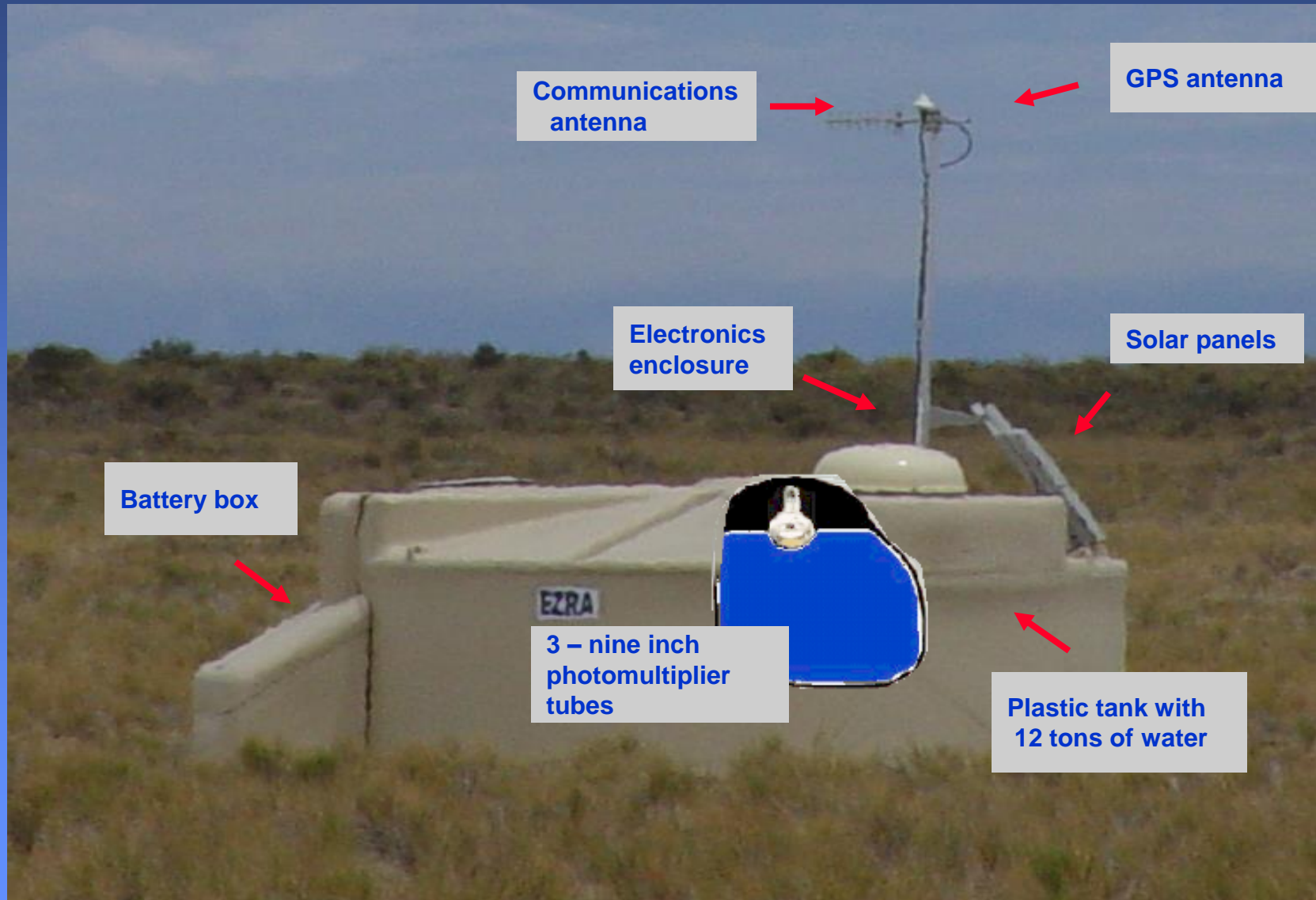
Concept to Reality



The Observatory Plan



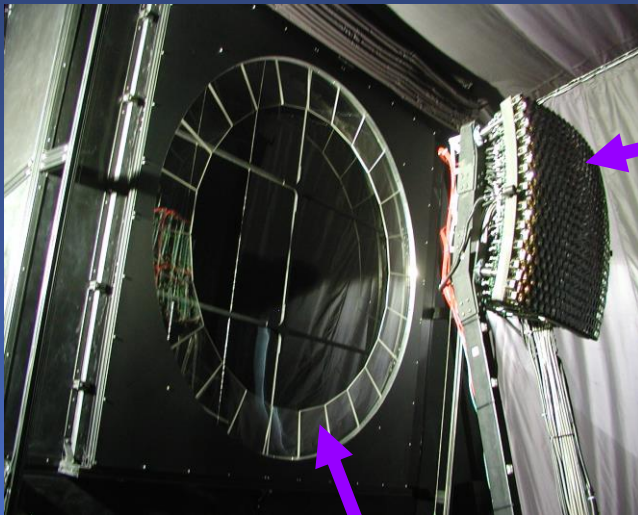
The Surface Array Detector Station



Surface detectors on the pampa



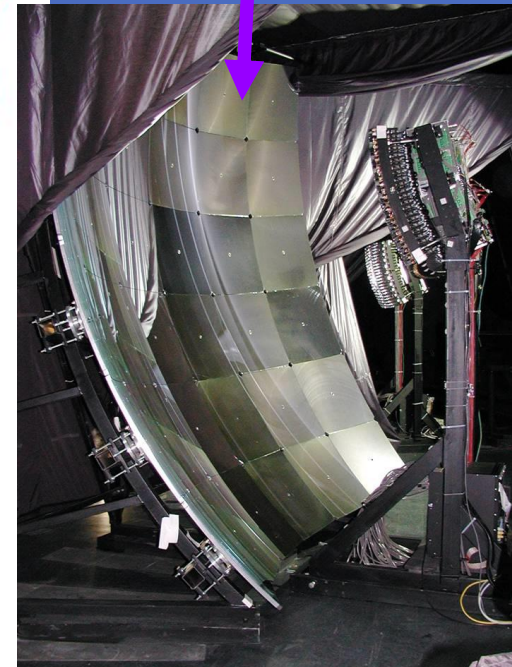
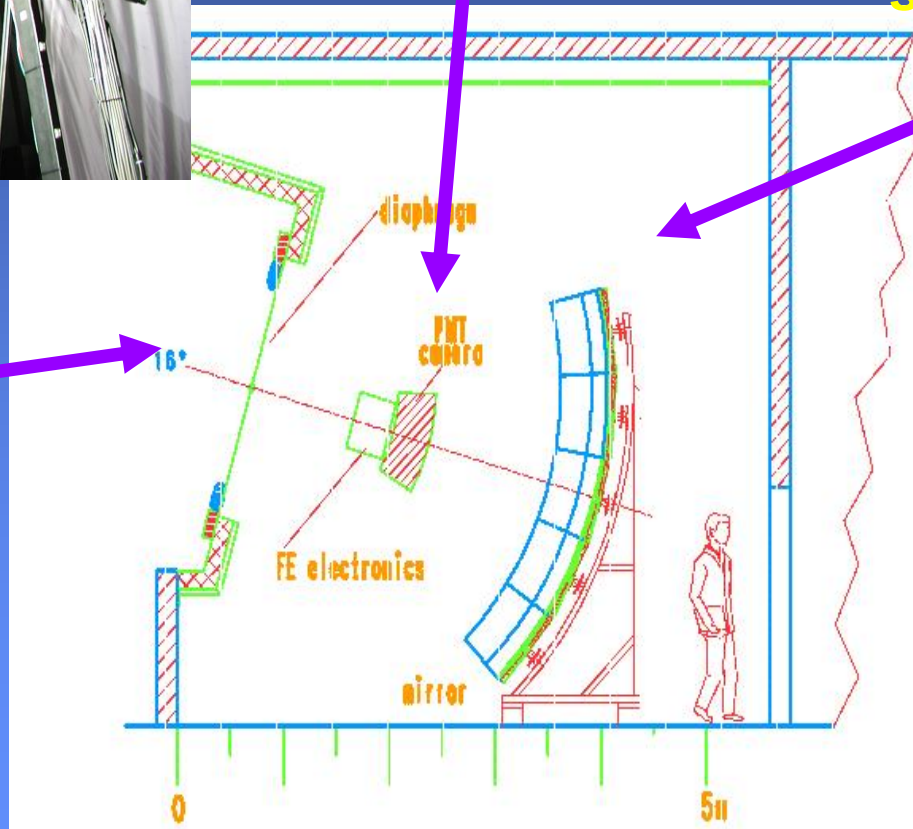
Fluorescence detector telescopes



440 pixel
camera

3.4 meter diameter
segmented mirror

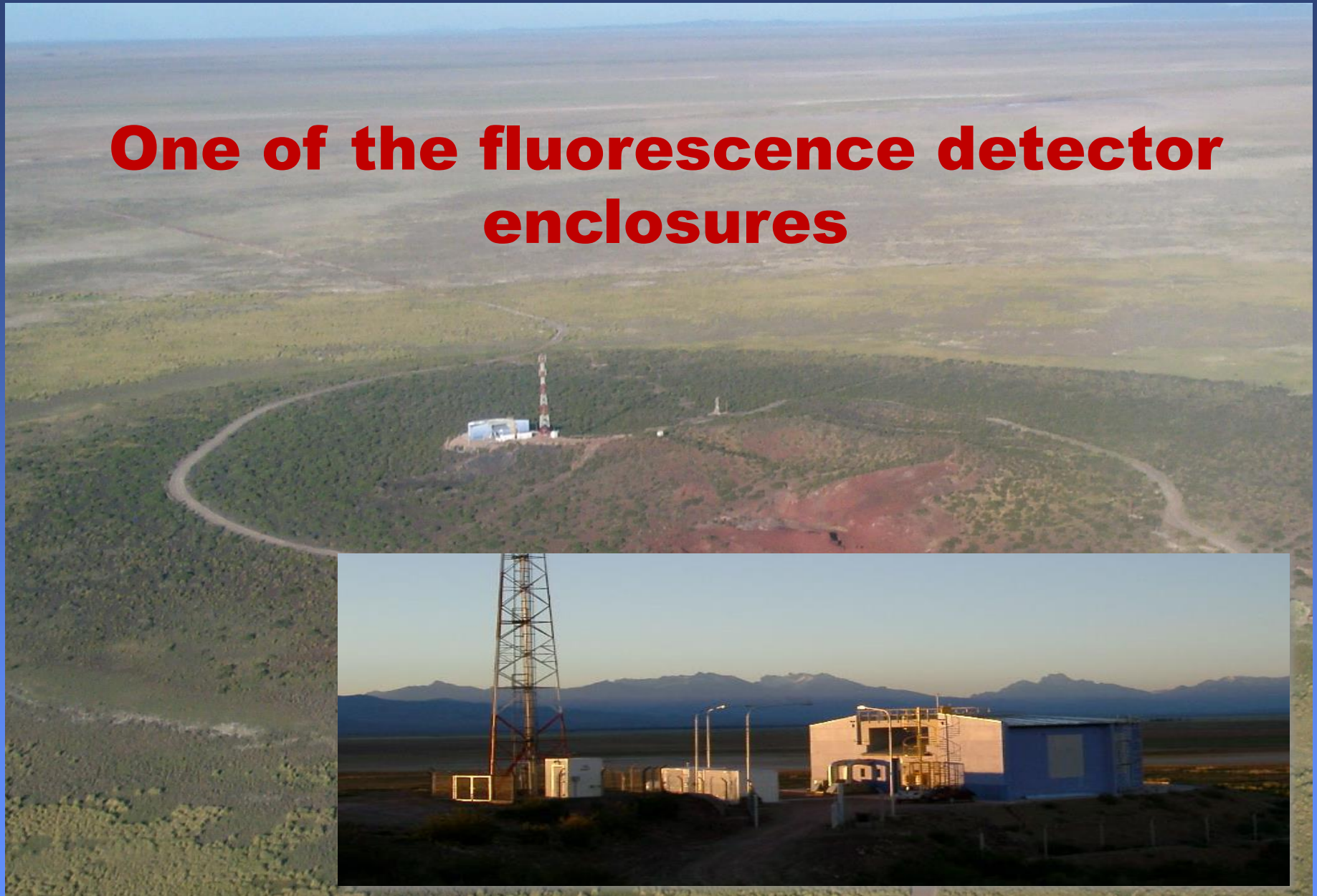
aperture
stop, filter,
corrector
lens



Six telescopes viewing 30° by 30°



One of the fluorescence detector enclosures



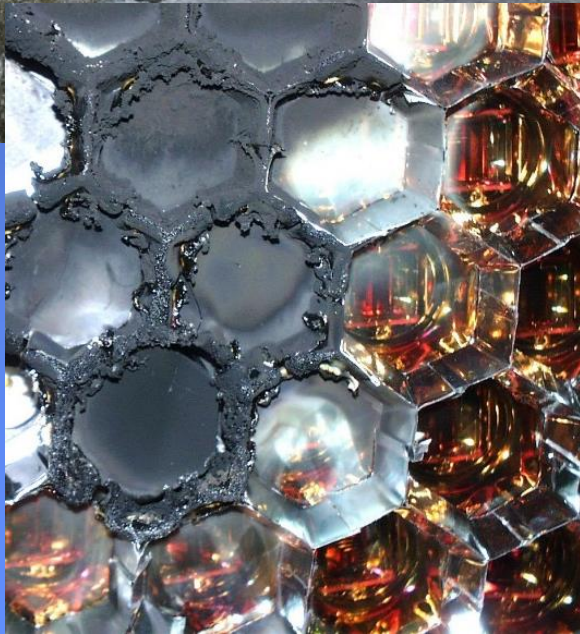
Deploying the Array



Communications



Not everything went smoothly



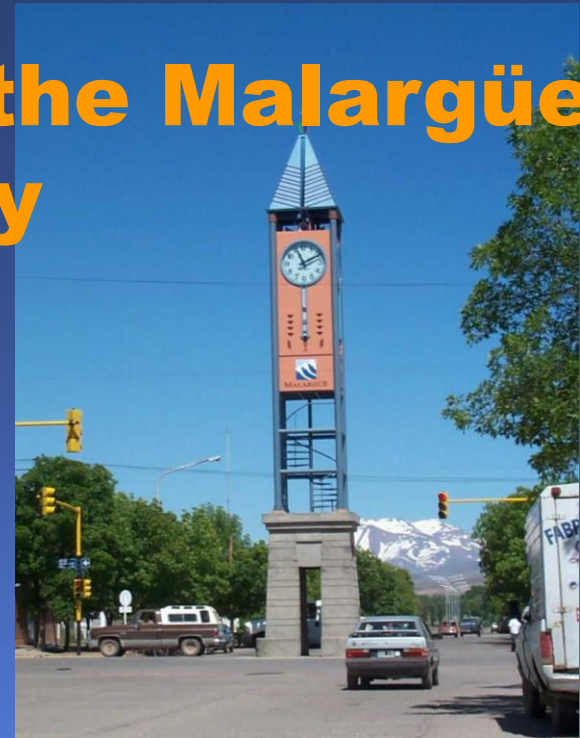
Auger Observatory Campus



Inauguration November 2008



The Observatory and the Malargüe Community



Impact - the Auger Observatory

Spectrum

Sources

Composition

New directions for future research in particle astrophysics

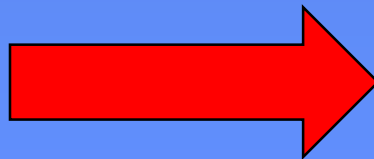
67 Journal papers

267 PhDs earned, 100 more coming.

Model for international science.

But there is more to come!

The AugerPrime upgrade



Science Magazine

22 September 2017

RESEARCH

COSMIC RAYS

Observation of a large-scale anisotropy in the arrival directions of cosmic rays above 8×10^{18} eV

The Pierre Auger Collaboration*†

Cosmic rays are atomic nuclei arriving from outer space that reach the highest energies observed in nature. Clues to their origin come from studying the distribution of their arrival directions. Using 3×10^4 cosmic rays with energies above 8×10^{18} electron volts, recorded with the Pierre Auger Observatory from a total exposure of $76,800 \text{ km}^2 \text{ sr year}$, we determined the existence of anisotropy in arrival directions. The anisotropy, detected at more than a 5.2σ level of significance, can be described by a dipole with an amplitude of $6.5_{-0.9}^{+1.3}$ percent toward right ascension $\alpha_d = 100 \pm 10$ degrees and declination $\delta_d = -24_{-13}^{+12}$ degrees. That direction indicates an extragalactic origin for these ultrahigh-energy particles.

Thank you